

Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches

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State Working Group Members

- Lawrence Bengal, Arkansas Oil and Gas Commission
- Douglas Johnson, Railroad Commission of Texas, retired
- Charles Lord, Oklahoma Corporation Commission
- James A Peterson, West Virginia Department of Environmental Protection
- Tom Tomastik ,Ohio Department of Natural Resources, retired
- Chuck Lowe, Ohio EPA
- Jim Milne, Colorado Oil and Gas Conservation Commission
- Denise Onyskiw, Colorado Oil and Gas Conservation Commission, retired
- Vince Matthews, Colorado Geologic Survey, retired

Expert Review Panel

- Brian Stump, Southern Methodist University
- Chris Hayward, Southern Methodist University
- Scott Ausbrooks, Arkansas Geological Survey
- Steve Horton, Center for Earthquake Research and Information, U of Memphis
- Ernest Majer, Lawrence Berkeley National Laboratory
- Norman Warpinski, Pinnacle
- John Satterfield, formerly with Chesapeake Energy
- Cliff Frohlich, Bureau of Economic Geology, University of Texas
- David Dillon, National Academy of Science
- Shah Kabir, Hess Energy
- Bill Smith, National Academy of Science, retired
- Roy Van Arsdale, University of Memphis
- Justin Rubenstein, USGS

Final Peer Review Panel

- Jeff Bull, Chesapeake Energy Corporation
- Robin McGuire, Lettis Consultants International, Inc.
- Craig Nicholson, University of California, Santa Barbara
- Kris Nygaard, ExxonMobil
- Heather Savage, Lamont-Doherty Earth Observatory, Columbia University
- Ed Steele, Swift Worldwide Services

Presentation Summary

- Overview of Study Approach
- Discussion of engineering tools
- Summary of findings and recommendations

Overview of Study Approach

- Timeframe for effort
 - Earthquakes were updated through 9/30/13.
 - References were updated as of 5/23/14.

Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- Development of decision model
- Fundamentals of induced seismicity
- Explore petroleum engineering methods

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Overview of Study Approach

- Literature review and compilation
 - Peer reviewed material only
 - Comprehensive, but moving target

Overview of Study Approach

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Overview of Study Approach

- Analysis of four case examples
 - Central Arkansas Area
 - North Texas Area
 - Braxton County, West Virginia
 - Youngstown, Ohio

Overview of Study Approach

- Analysis of four case examples
 - Geologic site summary
 - History of seismicity
 - State actions
 - Application of reservoir engineering methods
 - Lessons learned

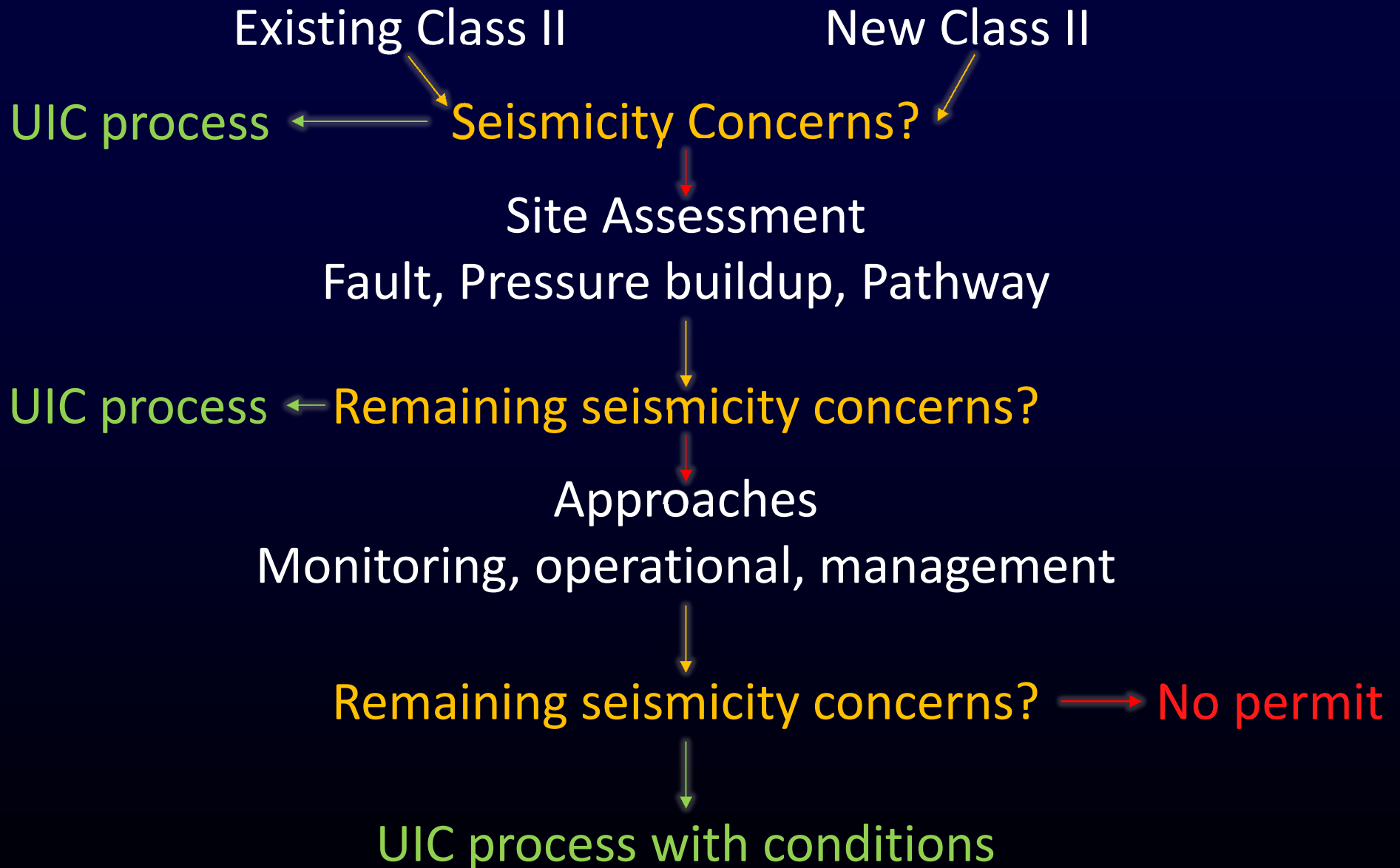
Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- **Development of decision model**
- Fundamentals of induced seismicity
- Explore petroleum engineering methods

Overview of Study Approach

- Development of decision model
 - Received much input throughout process
 - Comprehensive thought process - not specific
 - Founded on Director Discretionary Authority

DECISION MODEL FOR UIC DIRECTORS



Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- Development of decision model
- **Fundamentals of induced seismicity**
- Explore petroleum engineering methods

Overview of Study Approach

- Fundamentals of induced seismicity
 - Broader ^{DN1} potential audience
 - Provide a general reference
 - Includes geoscience and engineering aspects
 - Appendices of report

Slide 16

DN1

this slide did not make sense to me. is it to cover why we added the appendices?

Dorsey, Nancy, 1/26/2015

Overview of Study Approach

- Literature review and compilation
- Analysis of four case examples
- Development of decision model
- Fundamentals of induced seismicity
- Explore petroleum engineering methods

Overview of Study Approach

- Explore petroleum engineering methods
 - Data obtained from suspected wells in case examples were analyzed.
 - Two fundamental approaches were used.
 - Falloff testing.
 - Operational data analysis.

Presentation Summary

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- Discussion of engineering tools
- Summary findings and recommendations

Discussion of Engineering Tools

- A few points.
 - Quality of data is crucial.
 - These methods are an interpretive tool, not a fix-all.
 - PE tools can determine if fracture flow is predominant.
 - Fractured reservoirs can transmit pressure buildup over great distances.
 - PE tools can detect reservoir changes at distance, including faults.
 - Correspondence between well behavior and seismicity was apparent in some case example wells.

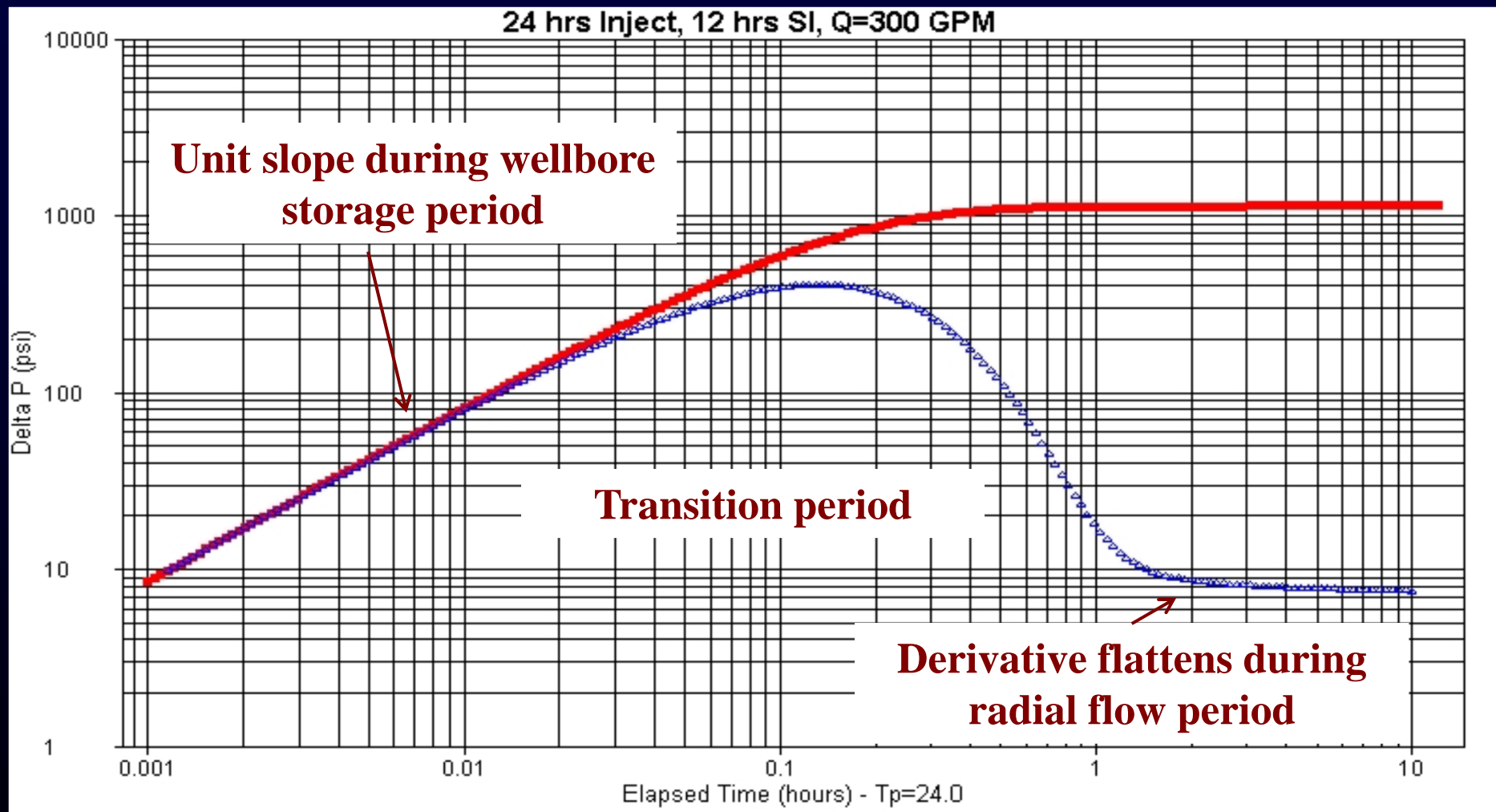
Discussion of Engineering Tools

- Two fundamental approaches
 - Well testing
 - Pressure transient or falloff testing can determine if a reservoir is fractured, as well as static formation pressure.
 - Function of near well conditions.
 - Analysis of operational data
 - Hall plots using operational data (rates and pressures) indicate changes in transmissivity (ease of injection) at distance.
 - Covers both near wellbore and distance increasing with time.

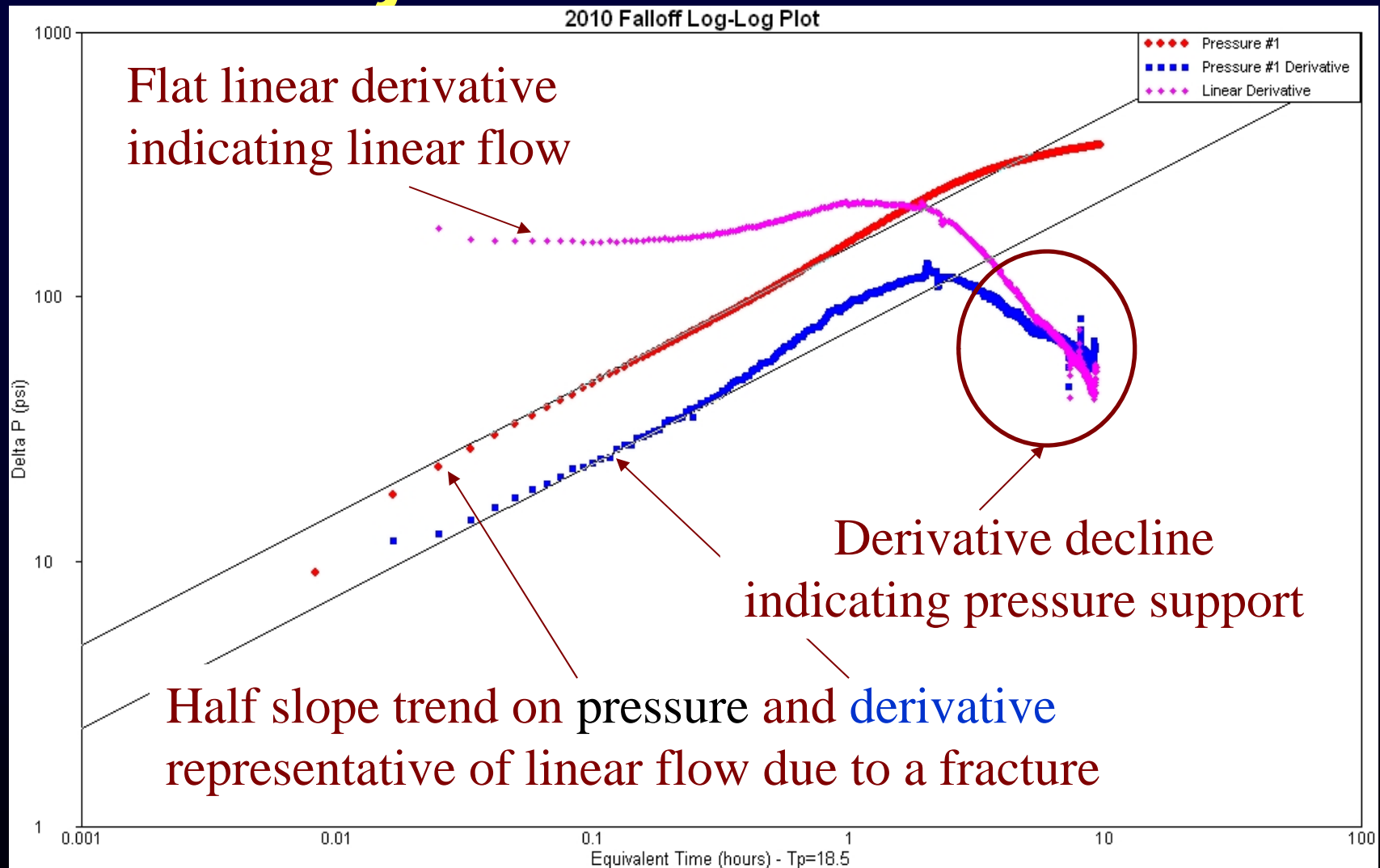
Discussion of Engineering Tools

- Examples – falloff testing

Log-Log Plot of a Disposal Well Exhibiting Radial Flow



Falloff Test Indicating Fractured Injection Formation



Discussion of Engineering Tools

- Examples – Hall plots

Presentation Summary

- Overview of Study Approach
- Aspects of engineering tools
- Summary of findings and recommendations

Summary of Findings and Recommendations

- Drop preconceptions of what is possible
- Realistic analysis not definitive proof
- Proactive approach is preferred
 - Engage operators
 - Additional site geologic data
 - Voluntary actions
 - Increased operational data
- Monitor seismicity trends in regional area

Summary of Findings and Recommendations

- Multi-disciplinary characterization of disposal reservoir (testing, analysis, consultation, literature)
 - Case examples – deep fractured reservoirs
 - Fractures more likely to communicate pressure buildup long distances
 - Buildup can be directional
 - Fractured reservoirs can result in communication with basement rocks, lower confining strata is important.

Summary of Findings and Recommendations

- Assure high quality operational data
- Permitting contingencies (green, yellow, red lights) are an excellent tool to address site uncertainties
- Increased seismometers better define seismic activity.

Summary of Findings and Recommendations

- Engage operators
 - Additional site geologic data
 - Voluntary actions
 - Increased operational data
- Monitor seismicity trends in regional area
- Characterize injection reservoir (testing)
 - Case examples – deep fractured reservoirs
 - Fractures more likely to communicate pressure buildup long distances
 - Buildup can be directional
 - Fractured reservoirs can result in communication with basement rocks

Final Words

- EPA Region 6 is preparing a seismicity training module for injection well regulators.